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IONITRIDING OF WEAPON COMPONENTS

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A program to evaluate ionitriding for the case-hardening of weapon system components was conducted by the Research Directorate, GEN Thomas J. Rodman Laboratory, Rock Island Arsenal. The study revealed advantages and limitations of the ionitriding process, and documented the production sequences required for the case-hardening of AISI 4140 and Nitralloy 135M steels. Determination of processing criteria included cleaning, loading, selective case-hardening, treatment times and temperatures, and geometric considerations. The production sequence was established for four weapon components presently manufactured at Rock Island

20. Arsenal. Evaluation of processing times and quality of the case-hardened components revealed that significant advantages are gained when the ionitriding process is used for production. (U) (BUSCH, Robert D.)

FOREWORD

The work was authorized as part of the Manufacturing Methods and Technology Program of the U. S. Army Mate-iei Command which is administered by the U. S. Army Production Equipment Agency.

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ILLUSTRATIONS

INTRODUCTION

The implementation of improved manufacturing technologies for fabrication of military hardware is one of the missions of the Research Directorate, GEN Thomas J. Rodman Laboratory, Rock Island Arsenal. As a part of this mission, a program was conducted to evaluate glow-discharge Ionitriding* as a case-hardening treatment for weapons components. The program involved the procurement of glow-discharge Ionitriding apparatus, evaluation and establishment of process procedures, training of production personnel, and application of Ionitriding for production of weapons components.

IONITRIDING

Process Description

Ionitriding is accomplished by the glow discharge of nitrogen and hydrogen ions upon selected component surfaces. Specifically, finished machine parts, which have been previously heat treated and thoroughly cleaned, are placed on an electrically insulated pedestal located in a vacuum chamber. The chamber is evacuated to less than 5×10^{-5} Torr pressure and is backfilled with a 3:1 ratio of nitrogen-hydrogen gas mixture to 0.5mm of mercury absolute-pressure. After backfilling, the glow discharge is initiated by application of a direct-current electrical potential between the chamber and the pedestal part. The gas pressure and the electrical potential are then slowly increased until an absolute pressure of 7mm mercury and a temperature of approximately 975°F are obtained. These conditions are maintained for a selected period of time by automatic temperature/power and gas pressure controllers. The process duration depends on the effective case depth required for the part. After the equipment has been shut off automatically and the parts cool to a temperature of less than 300°F, they are removed from the chamber.

Equipment

The equipment used for Ionitriding is shown in Figure 1. This equipment consists of a power/temperature control console, Ionitriding vacuum chamber, and a vacuum/gas control console.

*The term Ionitriding is the Registered Trade Mark of Klöckner Ionon GMBH.

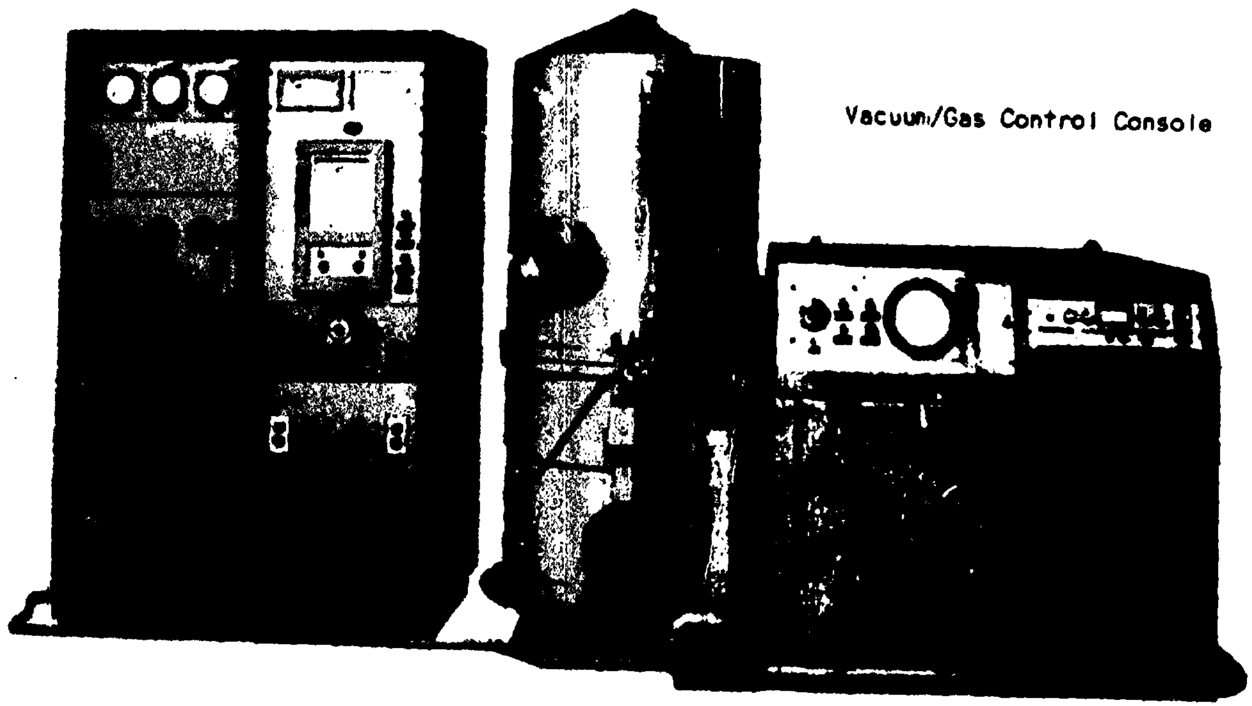

FIGURE 1. Ionitriding Equipment.

The power/temperature control console contains transformer and resistor tap switches for step control of the power input; a temperature/power control, which can be operated manually or automatically for continuous control of the stepped power; power input meters; and process time control.

The Ionitriding chamber consists of a water-cooled vacuum chamber 30 inches in diameter and 5 feet high. On the bottom of the chamber, an insulated pedestal is located for placement of parts to be Ionitrided.

The vacuum/gas control console contains vacuum pumps and controls, gas-flow regulator, and an automatic pressure regulator which controls the absolute pressure of the Ionitriding chamber.

The electrical power system, temperature control system, vacuum/gas control systems, and Ionitriding vacuum chamber layout are illustrated in the schematic shown in Figure 2.

PRODUCTION SEQUENCE

In the following sections, the process procedure established for the Ionitriding or case hardening of material is described.

Cleaning

The parts must be cleaned of surface contaminants which can hinder or completely stop the diffusion of nitrogen. These contaminants include organic materials, e.g., oils and greases; metallo-organic compounds, e.g., lithium and sodium base machining lubricants; and inorganic materials, e.g., oxides, copper, lead, etc. Vapor degreasing will only remove the organic compounds. The remaining contaminants must be removed by either buffing, glass shot blasting, or chemical stripping. After cleaning, care must be taken so the parts are not recontaminated.

Ionitriding Stopoff Techniques

Mechanical masking is the preferred method for the Ionitriding of selected areas of weapon components. The mechanical mask is normally fabricated from a low-carbon steel and usually fits the part with a clearance of 0.010 to 0.025 inch. A smaller clearance would cause the part to seize the mask.

Copper- or nickel-plating methods are unacceptable for selective Ionitriding. Copper sputters off the part and redeposits elsewhere on the part, thus preventing nitriding of required areas. Nickel plating

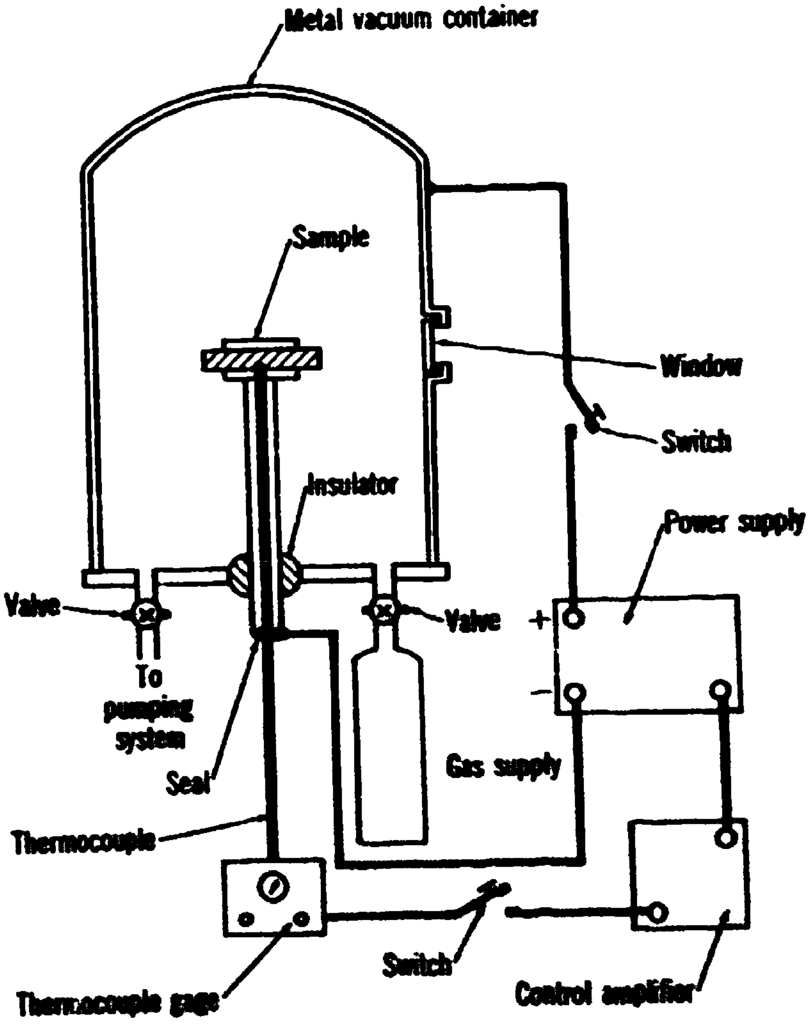

FIGURE 2. Schematic of Ionitriding Equipment

does not sputter off, but diffuses into the surface of the part and cannot be removed. Nickel plating over copper is unacceptable because defects in the nickel allow the copper to sputter off the part and redeposit elsewhere.

Loading

The parts to be Ionitrided are loaded on an electrically conductive fixture similar to the one shown in Figure 3. The parts must be spaced no closer than 0.30-inch or overheating will result caused by overlapping glow in the spaces between parts. The loaded fixture is then placed on the insulated pedestal, and the vacuum-chamber top put in place.

Glow Initiation and Heating

After the parts have been loaded and the Ionitriding chamber closed, the system is evacuated to 5×10^{-5} Torr absolute-pressure. The chamber is then backfilled with a 3:1 ratio of hydrogen-nitrogen gas mixture to 0.5mm of mercury absolute-pressure. The glow discharge is initiated by application of a direct current electrical potential between the cathodic pedestal and the anodic vacuum chamber walls.

During the initial heating and cleaning phase, flashing will be observed on the surface of the parts caused by metal flakes and adsorbed gases being removed. The power should not be increased until this flashing has subsided , or the surface of the part will be etched. After flashing has subsided, the power is slowly increased so the part does not heat faster than 1000°F per hour. When the temperature has reached 500°F, the gas pressure is increased to 4mm mercury, absolute. At this point, the gas pressure and power are increased simultaneously until 7mm mercury absolute-pressure and the selected Ionitriding temperature are obtained. These conditions are then maintained for a selected time by automatic controllers.

Process Time and Temperature

Process times to obtain effective case depths were established experimentally for Nitralloy 135M and for AISI 4140 steels. These steels are commonly used for the manufacture of nitrided weapons components. A temperature of 1050°F, upper limit for Ionitriding, was selected for the Nitralloy 135M to keep treatment times short. Since AISI 4140 contains no aluminum ad the Nitralloy 135M does, a lower case hardness results due to an absence of aluminum nitride precipitation. Consequently, an Ionitriding temperature of 975°F was selected to provide a higher surface hardness for the AISI 4140 steel.

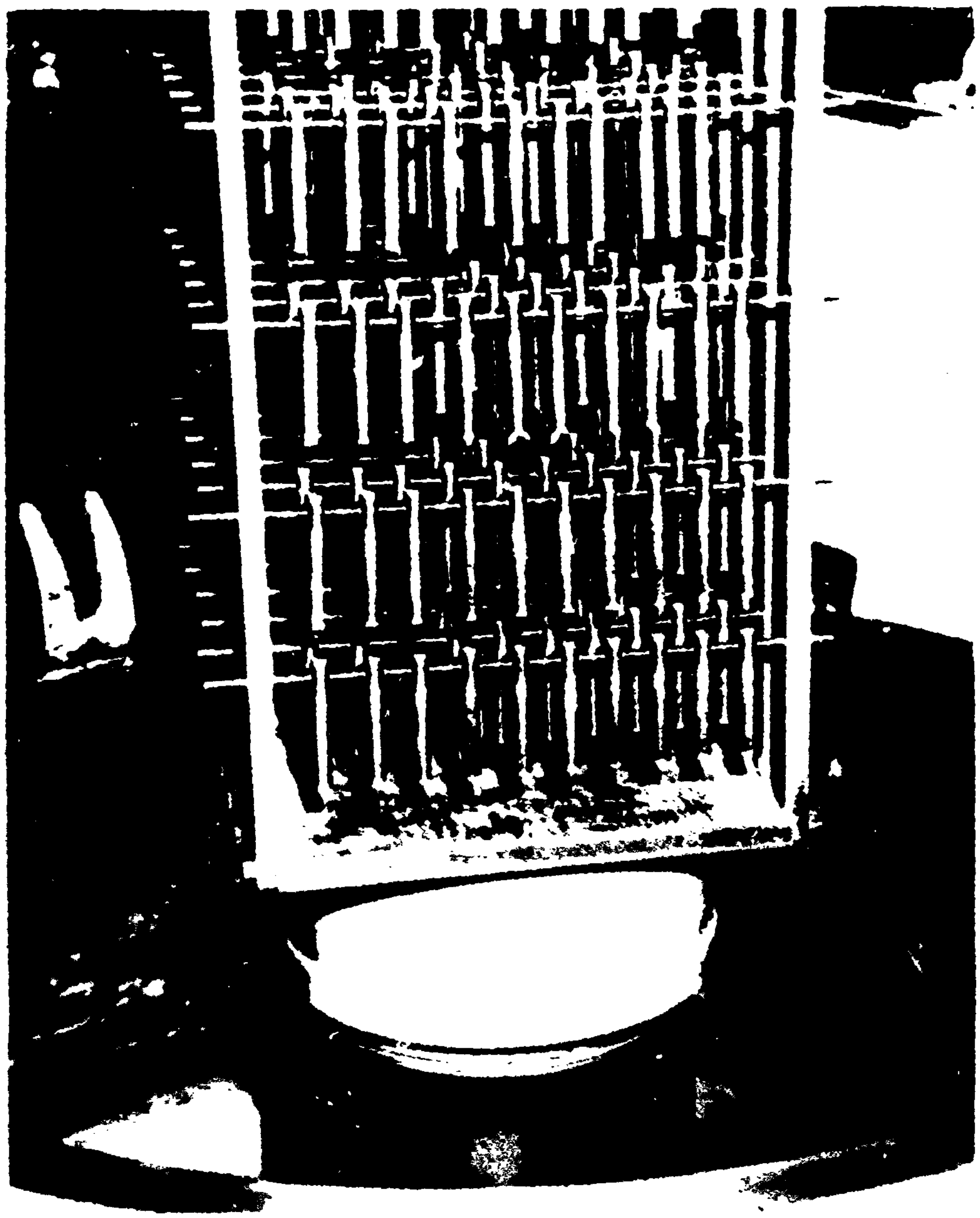

FIGURE 3. Cathode Fixture Utilized in the Production Ionitriding of the Push Rod for MAU-69 A/A Weapon

PRODUCTION IONITRIDING

The procedure described in the previous sections was utilized for the production Ionitriding of four components. These components are: Push Rod, Part 6589833 for the MAU-69NA; Roller Shaft, Part 10892032 for the M158; and two Spur Gears, Parts 13207E3044 and 13207E3050 for a Marine Drive Assembly.

Push Rod

The push rod, shown in Figure 4, was finish machined from AISI 4140 steel and heat treated to Rockwell C 38. This part was Ionitrided at 975°F for 8 hours. The results were:

Requirements	Results
Core Hardness, R_C 35 minimum	R_C 37
Effective Case Depth, 0.004- to 0.006-inch	0.005-inch
White Layer Thickness, 0.0005-inch maximum	0.0002-inch

The conventional gas nitriding time to obtain the above requirements is a minimum of 14 hours.

Roller Shaft

The roller shaft, shown in Figure 5, was finish machined from Nitralloy 135M heat treated to Rockwell C 37. The part was Ionitrided at 1050°F for 10 hours to obtain the desired effective case depth. The results were:

Requirements	Results
Core Hardness, No limits specified	R_C 32
Effective Case Depth, 0.005- to 0.009-inch	0.009-inch
White Layer Thickness, No limits specified	0.0003-inch

Conventional gas nitriding would have required about 22 hours to obtain an equivalent case depth.

Spur Gears

The spur gears, shown in Figure 6, were finish machined from Nitralloy

FIGURE 4. Push Rod, Part 65B9833 for MAU-69 A/A (2X)

FIGURE 5. Roller Shaft, Part 10892032 for the M158 Weapon

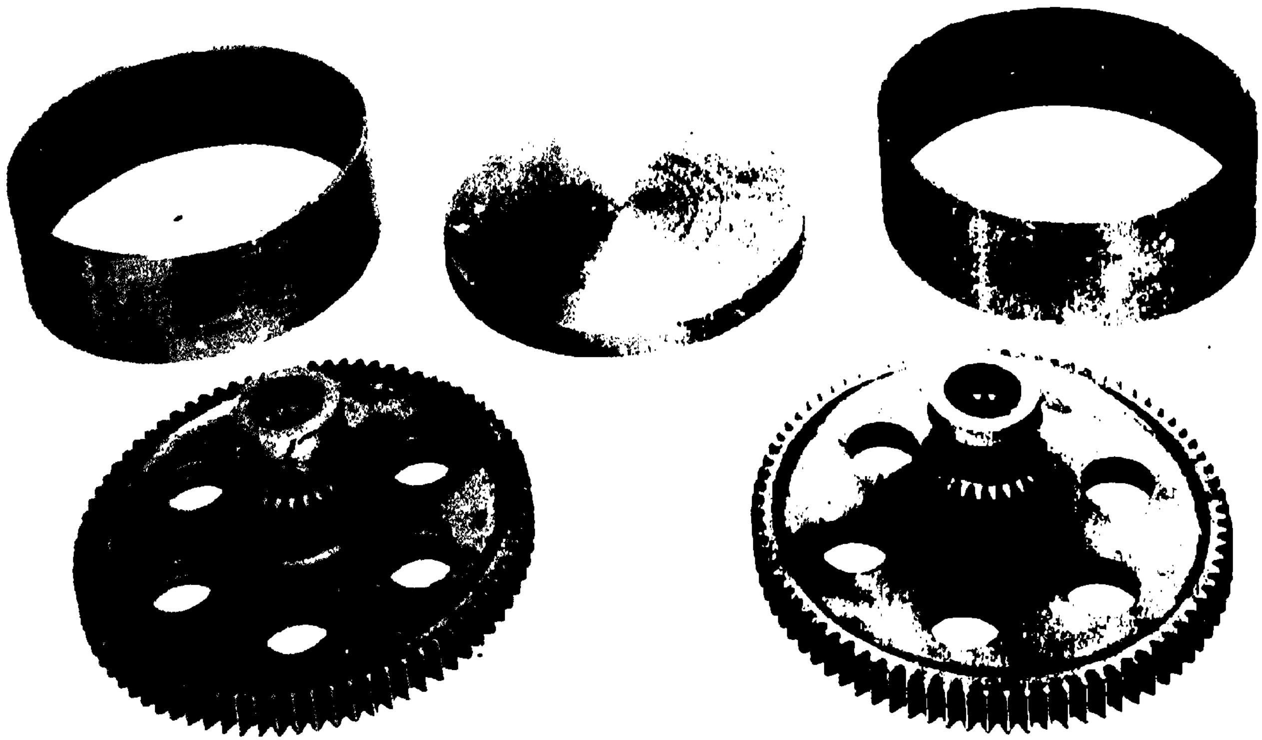

FIGURE 6. Disassembled Mechanical Musk Utilized for Selective Production Nitriding of Marine Drive Spur Gears (Parts 13207E3044 and 13207E3050).

135M and heat treated to Rockwell C 36. The gears were ionitrided at 1050°F for 28 hours to obtain the minimum effective case depth requirements at the roots of the gear teeth. The gears were selectively nitrided by use of a mechanical mask, as shown in Figures 6 and 7. The results were:

Requirements	Results
Core Hardness, R_C 32-38	R_C 36
Case Surface Hardness, R15N, 89.5 minimum	R15N 92
Effective Case Depth, 0.012- to 0.019-inch	Root 0.014-inch Point 0.019-inch
White Layer Thickness, 0.0005-inch minimum	0.0006-inch

DISCUSSION

Advantages

Ionitriding has two distinct advantages over conventional gas nitriding. First, process times are shorter for ionitriding than for either conventional single-stage or double-stage (Floe) gas nitriding. This is shown in Figures 8 and 9 in which the effective case depth versus nitriding times, established for Nitralloy 135M and AISI 4140 steels, is compared. The reduced processing times for ionitriding not only lowered the production cost of the nitrided parts but provided improved mechanical property values when compared to conventional gas nitriding. A comparison of mechanical property values is shown in Table I.

The second advantage is that ionitriding produces a thinner white layer than conventional gas nitriding. As shown in Figure 10 and 11, ionitriding usually keeps the white layer below the thickness of 0.0005-inch. Above this limit, the white layer is usually considered detrimental to the part and must be removed by mechanical or chemical methods which increase processing costs. Conventional gas nitriding usually exceeds this limit of 0.0005-inch.

Limitations

Part geometry affects the ionitriding of weapon components. Small diameter holes and narrow slots (about 0.1-inch or less) cannot be ionitrided because the glow discharge will not penetrate into these narrow configurations. Larger diameter long tubes and holes cannot be ionitrided uniformly unless a center anode is used to provide an even electrical

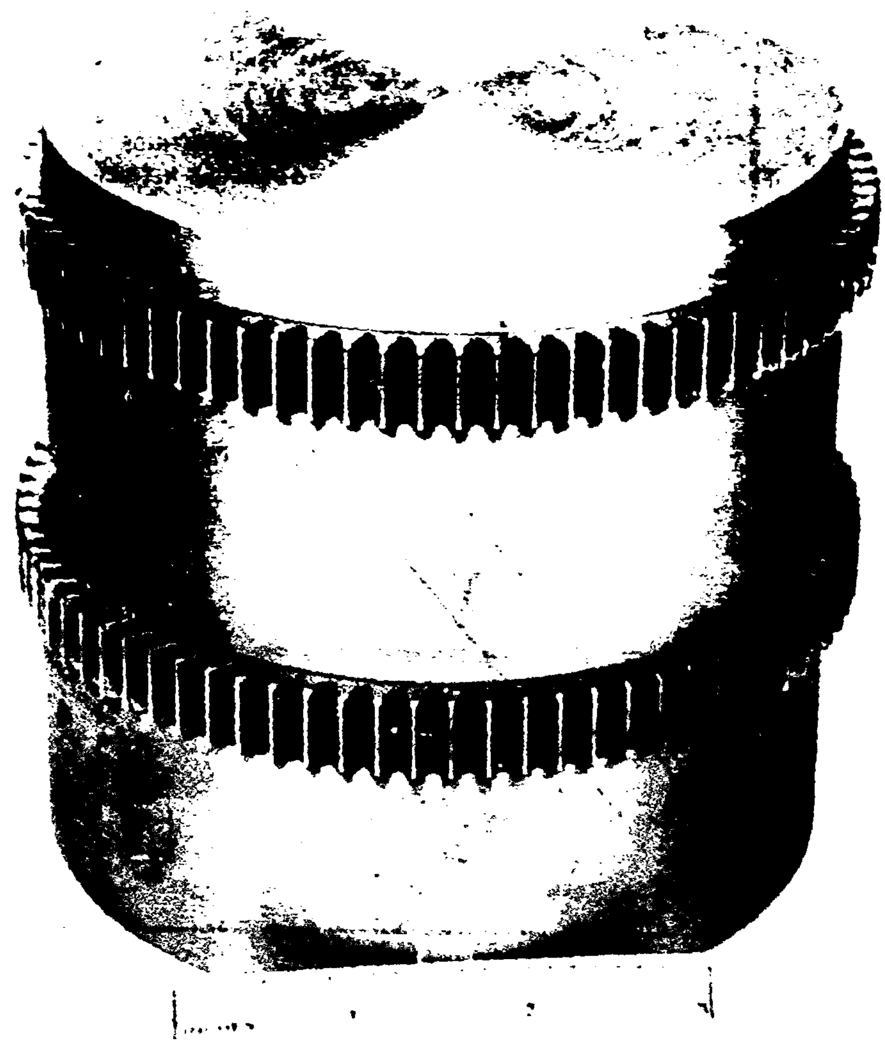

FIGURE 7. Assembled Mechanical Mask and Marine Drive Spur Gears Shown In Figure 6.

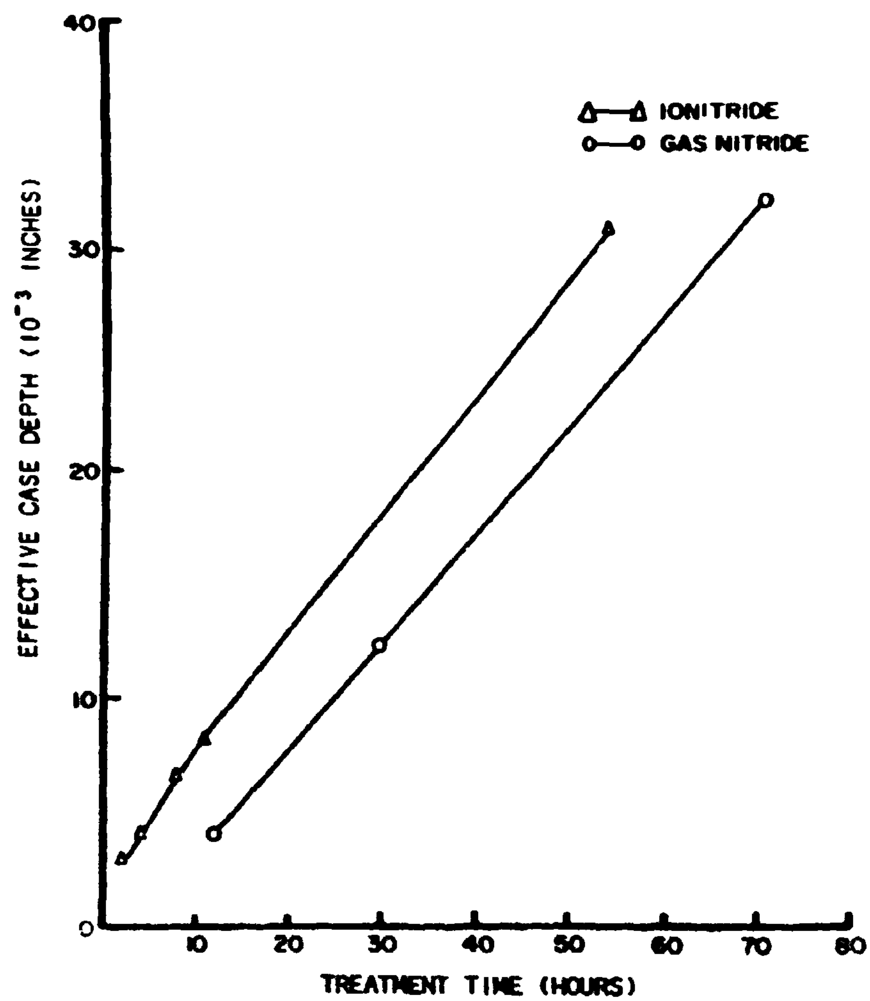

FIGURE 8. Comparison of Effective Case Depth Versus Treatment Time for Conventional and Ionitrided 4140

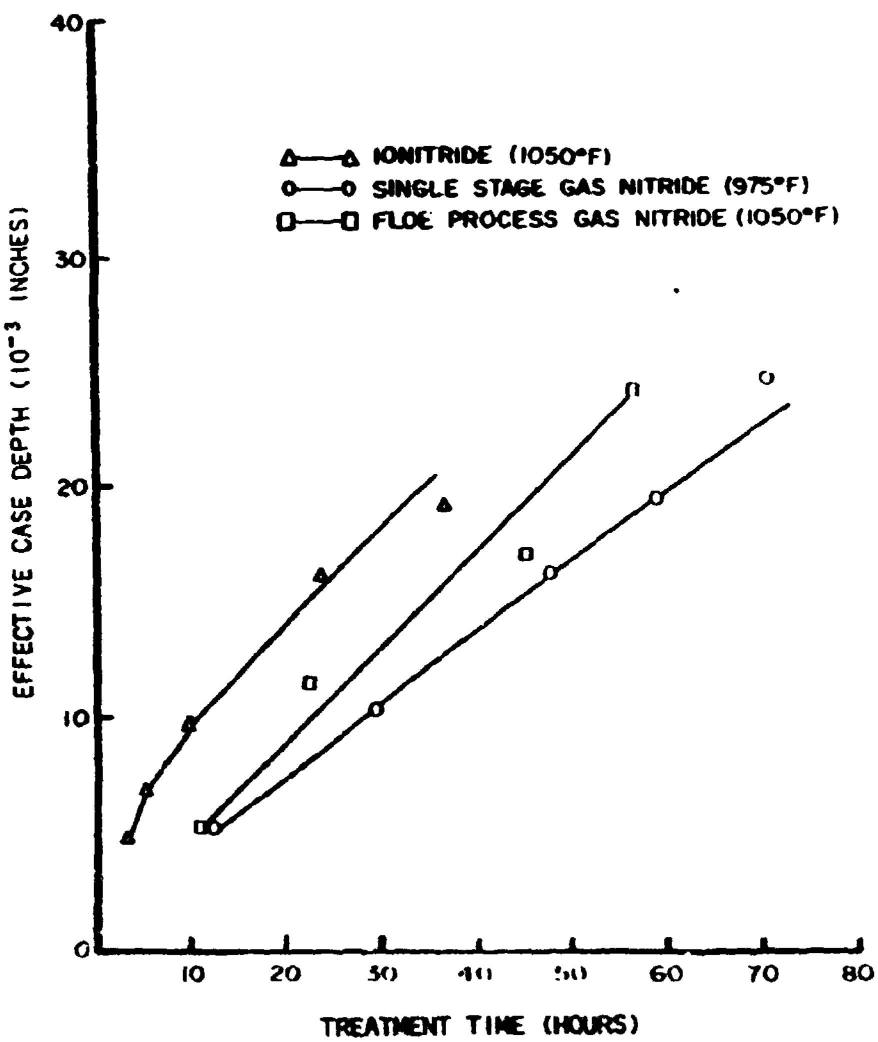

FIGURE 9. Comparison of Effective Case Depth Versus Treatment Time for Ionitriding, Conventional Nitriding, and the Floe Process for Nitralloy 135M Steel.

TABLE 1. MECHANICAL PROPERTIES OF NITRALLOY 135M

TREATMENT	TENSILE PROPERTIES*				WEAR TEST*	
	% REDUCTION OF AREA	% ELONGATION	YIELD (Ksi)	TENSILE (Ksi)	AVG. COEFF. OF FRICTION	RATE OF WEAR ($mg/cm^2/min.$)
NO TREATMENT	59.7	16.4	131	150	1.28	63.20
GAS NITRIDED**	33.4	11.3	131	150	1.28	0.19
IONITRIDED***	35.4	12.7	129	151	1.03	0.13

* Average of three tests.

** One-step gas nitrided at 975°F for 12 hours, 0.004-inch effective case depth.

*** Ionitrided at 975°F for 12 hours, 0.006-inch effective case depth.

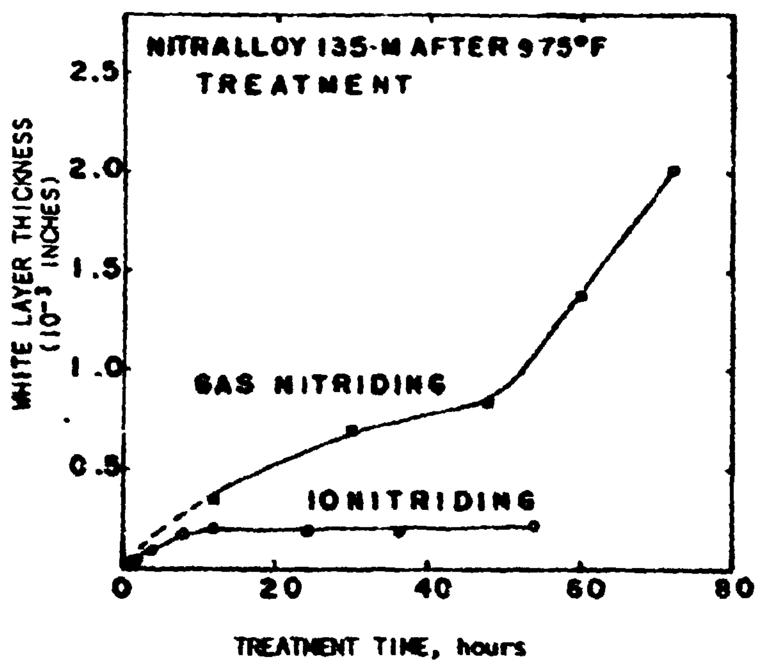

FIGURE 10. Comparison of White-Layer Thickness on Gas Nitrided and Ionitrided Nitralloy 135 N Steel

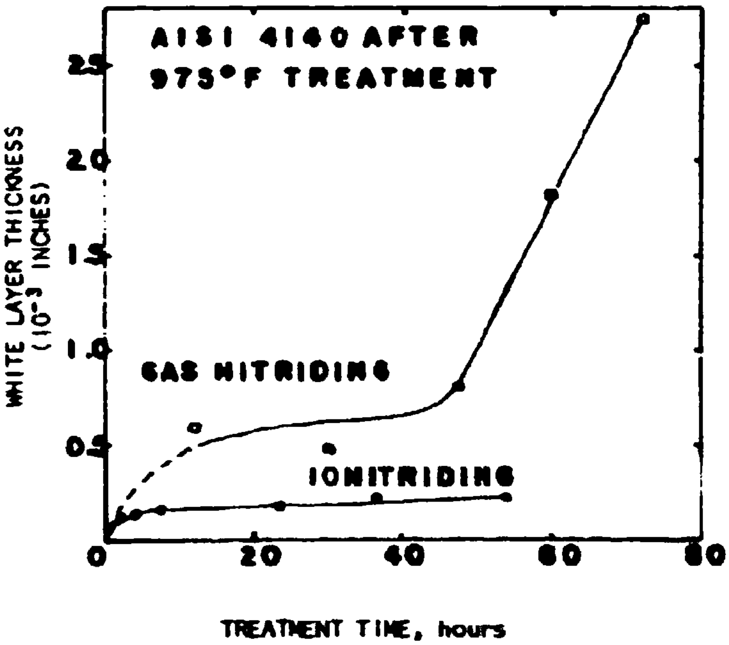

FIGURE 11. Comparison of White-Layer Thickness on Gas Nitrided and Ionitrided 4140

potential for the glow discharge. These effects mean that gun barrels less than 7.62mm bore size cannot be ionitrided and larger diameter gun barrels can only be ionitrided with the use of a center anode.

For gears with small diametral pitch, the roots of the teeth will have less nitriding than the points. As the pitch increases, the nitriding of the teeth roots will approach that of the teeth points.

CONCLUSIONS

1. Ionitriding is applicable to the case hardening of weapon components.

2. Cost savings result from reduced treatment times and by the elimination of white layer removal requirements.

3. Ionitriding can be utilized as an alternate to conventional nitriding without changes in mechanical property specifications.

SUMMARY

After training of production personnel, the ionitriding procedures described herein have been implemented by the Arsenal Operations Directorate of Rock Island Arsenal.